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①1 Publication number : **0 649 041 A1**

①2 **EUROPEAN PATENT APPLICATION**

②1 Application number : **94307487.2**

⑤1 Int. Cl.<sup>6</sup> : **G02B 6/42**

②2 Date of filing : **12.10.94**

③0 Priority : **18.10.93 US 138684**

④3 Date of publication of application :  
**19.04.95 Bulletin 95/16**

⑧4 Designated Contracting States :  
**DE FR GB IT**

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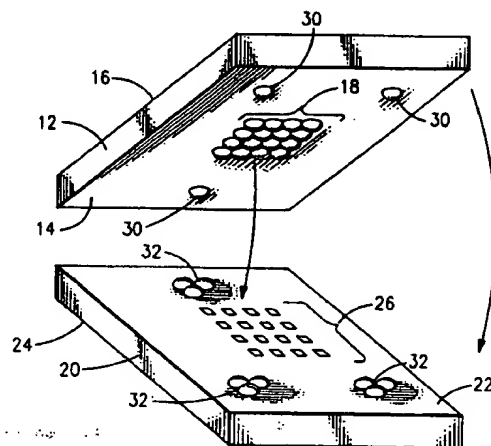
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⑤4 **A microelement assembly.**

⑤7 A microelement assembly (10) includes first and second substrates, (12) and (20). One of the substrates (12) includes, as an integral part thereof, at least three kinematic protrusions (30) whereas the other substrate (20) includes, as an integral part thereof, a corresponding number of kinematic receptacles (32) whereby the first and second substrates, (12) and (20), are uniquely aligned when assembled.

**FIG.2**



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## BACKGROUND OF THE INVENTION

The present invention generally relates to a microelement assembly and, in particular, relates to one such microelement assembly having means, integrally formed in each of two substrates, for kinematically interfacing the substrates to each other.

As used herein the phrase "microelement", and all idiomatic variations thereof, is taken to include any and all optical or electronic elements having features that are formed by other than known industrial machining techniques.

Currently, when two or more substrates having microelements thereon are to be assembled, the alignment of the substrates prior to final attachment thereof is quite tedious and subject to considerable human error. For example, typically when substrates containing two microelectronic circuits are to be assembled to each other, alignment fiducials are provided on each substrate at some point during the manufacturing processing of those circuits. In many cases, the fiducials are aligned using an infrared microscope and, once aligned, the circuits are subsequently affixed to each other. One particular application of the microelements under discussion is the alignment and attachment of a substrate having electronic signal processing circuitry thereon to a substrate having a multi-element detector array thereon. Further, when two or more substrates having optical microelements thereon are to be aligned, for example, when a lenslet array is to be aligned with another substrate having optical microelements, such as an array of laser diodes, similar alignment techniques are used. However, in the case of substrates having optical microelement alignment, the alignment can nonetheless be performed by use of a microscope, however the party performing the alignment usually has to actually look through one of the optical microelement substrates to align the fiducials. Similar techniques are used when a substrate having optical microelements and a substrate having an electronic microelement are to be aligned with each other, such as in the case of disposing a lenslet array over a detector array.

The alignment schemes described above have a number of drawbacks. Specifically, the initial alignment is clearly subject to human error. Further, since the substrates must usually be retained in position until one or more steps are performed to affix the substrates to each other, an operator is required to maintain the alignment over a period of time. Such a requirement is also subject to not only the usual visual human error but is also subject to errors introduced during the period of attachment. Such human errors are compounded as microelements continue to increase in element density and/or get smaller as the optical and electronic technologies advance.

Hence, a microelement assembly that overcomes the above recited drawbacks and eliminates the need

for sustained operator alignment is highly desired.

## SUMMARY OF THE INVENTION

Accordingly, it is one object of the present invention to provide a microelement assembly that substantially completely overcomes the above recited drawbacks of conventional microelement assemblies.

This object is accomplished, at least in part, by the provision of a microelement assembly having means, integrally formed in each of two substrates, for kinematically interfacing the substrates to each other such that alignment of the microelements is accurate and unique.

Other objects and advantages of the present invention will become apparent to those skilled in the art from the following detailed description read in conjunction with the appended claims and the drawings attached hereto.

## BRIEF DESCRIPTION OF THE DRAWINGS

The drawings, not drawn to scale, include:

Figure 1 which is a cross-sectional view of a microelement assembly of two substrates having microelements thereon embodying the principles of the present invention;

Figure 2 which is a perspective view of the microelement assembly of two substrates shown in Figure 1 embodying the principles of the present invention;

Figure 3 which is a graph showing bump height versus hemisphere spacing; and

Figure 4A-4E which depict a series of steps showing a method for fabricating and assembling two microelement substrates in accordance with the method of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

A microelement assembly, generally indicated at 10 in the drawings and embodying the principles of the present invention, includes a first substrate 12 having first and second major surfaces, 14 and 16, respectively, and including a first microelement 18, a second substrate 20 having first and second major surfaces, 22 and 24, respectively, and including at least a second microelement 26 thereon, and means 28, formed at each of at least three mounting locations on both of the first major surfaces, 14 and 22, of the first and second substrates, 12 and 20, respectively, for kinematically interfacing the first and second substrates, 12 and 20, respectively, to each other such that the first and second microelements, 18 and 26, respectively, thereon are aligned with each other. As used herein the phrase "kinematic interfacing" or "kinematic mounting", as well as any idiomatic forms thereof, is taken to contemplate the unique constrain-

ed mating of two structures. Further, in most instances, in order to ensure that the alignment is unique, the three points are not ordinarily arranged in the form of an equilateral triangle. However, such a limitation is readily removed by the provision of different interface arrangements at, minimally, one of the three points.

In one particular embodiment, the first and second microelements, 18 and 26, respectively, associated with the first and second substrates, 12 and 20, respectively, are disposed such that the first major surfaces, 14 and 22, respectively, thereof, when assembled, are proximate each other. In the embodiment shown in Figures 1 and 2, the first substrate 12, for the sake of discussions purposes only, is described herein as having a first micro lenslet array as the microelement 18 and the second substrate 20 is described as an array of laser diodes as the microelement 26. As shown, the first substrate 12 includes the micro lenslet array formed on the first major surface 14 thereof such that the lenslet array, when assembled with the second substrate 20, is proximate the laser diodes formed on the first major surface 22 of the second substrate 20.

In the preferred embodiment, the means 28 for kinematically interfacing the first and second substrates, 12 and 20, respectively, includes at least three kinematic mounting protrusions 30 disposed on and extending from the first major surface 14 of the first substrate 12 and an equal number of kinematic mounting receptacles 32 disposed on the first major surface 22 of the second substrate 20 and positioned to kinematically interface with the protrusions 30. Preferably, although not necessarily, in one preferred embodiment, the protrusions 30 are formed in the shape of hemispheres. Further, in the embodiment shown, each of the kinematic mounting receptacles 32 includes at least three discrete hemispherical bumps. Each set of bumps constituting one of the kinematic mounting receptacles 32 are preferably arranged to kinematically contact one of the kinematic mounting protrusions 30 at no less than three points. As more fully discussed below, the protrusions 30 and the kinematic mounting receptacles 32 are preferably formed during the fabrication of the microelements, 18 and 26, respectively.

The dimensions of the protrusions 30 and the bumps of the kinematic mounting receptacles 32 will depend on the particular microelements, 18 and 26, on the substrates, 12 and 20, as well as on the particular methods of fabricating those elements. Nonetheless, the following example provides more than sufficient information to allow those skilled in the art of microelements to implement the assembly 10 without any undue experimentation.

In one specific embodiment, the individual lenslets of the lenslet array on the first substrate 12 are each taken to have a focal length of about 200 micrometers. Hence, to collimate light emitted from the di-

odes, the first major surfaces, 14 and 22, of the first and second substrates, 12 and 20, respectively, are spaced apart by the distance of the focal length, i. e., about 200 micrometers. Further, the spacing of the adjacent lenslets of the lenslet array will be equal to the spacing of the diodes of the diode array, which, although not critical to the practice of the present invention will, in this example, be taken to be about 50 micrometers. Operationally, in order to efficiently collimate the output of the laser diodes, the diodes must be accurately aligned with the lenslets.

Hence, to ensure the alignment of the lenslet array with the diode array in both the x and y directions the protrusions 30 and the kinematic mounting receptacles 32 must be very accurately sized and positioned on the first major surfaces, 14 and 22, of the first and second substrates, 12 and 20, respectively. Once the focal length is ascertained, i. e., the determination of the separation distance 'h' between the first major surfaces, 14 and 22, the radius of the hemispheres for the protrusions 30 and the bumps of the kinematic mounting receptacles 32 is selected. Typically, to readily ensure three points of contact between each protrusion 30 and the corresponding receptacle 32, the radius is selected to be less than the distance 'h' but more than half of that distance. In the present embodiment, for example, with a focal length of about 200 micrometers, a radius of about 150 micrometers is selected. The distance 'd' between the bumps of the kinematic mounting receptacles 32 is then selected to be slightly greater than twice the radius of the hemispheres. The determination of the distance 'd' can, in the preferred embodiment be ascertained by graphically plotting the equation:

$$h(d) = 2 \cdot r \cdot \sin[\theta(d)],$$

wherein;

h(d) is the spacing between the first surfaces, 14 and 22;

d is the distance between the bumps;

r is the radius of the hemispheres (in this example, 150 micrometers);

$\theta(d)$  equals  $\arccos(d/4r)$ .

The graph shown in Figure 3 is a plot of the solution of the above equation for values of 'd' ranging from 300 micrometers to 550 micrometers. In the present example, since the spacing between the first major surfaces, 14 and 22, is known, i. e., selected to be 200 micrometers, the distance 'd' between the bumps of each kinematic mounting receptacle 32 is determined from the graph to be slightly less than 450 micrometers.

Preferably, the bumps of each kinematic mounting receptacle 32 are disposed so that when the protrusions 30 of the first substrate 12 are brought into contact with the bumps of the respective kinematic mounting receptacles 32, each protrusion 30 makes equal contact with each bump of the kinematic mounting receptacles 32. The resulting three point contact

uniquely fixes the position of each protrusion 30 within the corresponding kinematic mounting receptacles 32 and, hence, uniquely fixes the first and second substrates, 12 and 20, respectively, with respect to each other.

The protrusions 30 and the kinematic mounting receptacles 32 are preferably located and established during the fabrication of each of the substrates, 12 and 20. As shown in Figure 4A, the first and second substrates, 12 and 20, respectively, are each initially provided with a layer 34 of photosensitive material, such as photoresist, that is disposed over the first major surfaces, 14 and 22, respectively, thereof. In the present example, as shown in Figure 4B, a plurality of openings 36 are formed in the layer 34 of photoresist by, for example, a photolithography step. The photolithography step results in openings 36 that, in the first substrate 12, are the locations for the protrusions 30. Similarly, the photolithographic step applied to the second substrate 20 results in openings 36 that are the locations for the three positions of each of the kinematic mounting receptacles 32. Because of the accuracy inherent with a process such as photolithography, the protrusions 30 and kinematic mounting receptacles 32 are thus very accurately aligned with each other. Further, such accurate alignment is quite repeatable.

As shown in Figure 4C, before the remainder of the layer 34 of photoresist is removed, electrically conductive bumps 38 are formed at the opened locations. In one particular embodiment, the bumps 38 are formed using an indium solder. Alternatively, the bumps 38 can be formed from plastic, glasses, metals or the like. Typically, the indium bumps are formed by known electrodeposition processes.

Thereafter, as shown in Figure 4D, the remainder of the layer 34 of photoresist is removed. After the removal, the bumps 38, as shown in Figure 4E, are formed into hemispheres 40 by heating the bumps 38 to the melting point of the material and allowing the material to flow into the hemispherical shape. The melting point and the time allowed for the material to flow are, of course, dependent upon the properties of the material used to form the bumps 38. Advantageously, by the use of an electrically conductive material having a relatively low melting point, such as indium solder, for the bumps 38, the bumps 38 can also be used as the connection for rigidly affixing the first and second substrates together. Hence, from the above, it will be understood that any number of substrates can be assembled so long as the substrates can be treated with a photolithographic processing step.

Although the present invention has been described herein with respect to one or more specific embodiment, it will be understood by those skilled in the art that other arrangements and configurations can also be made that do not depart from the spirit and

scope of the present invention. Consequently, the present invention is deemed limited only by the appended claims and the reasonable interpretation thereof.

## Claims

### 1. A microelement assembly, comprising:

first and second substrates, each said substrate having at least one microelement associated therewith, each said substrate having a first surface proximate each other; and

means, formed at each of at least three mounting locations on each said first surface of said first and second substrates, for kinematically interfacing said first and second substrates to each other such that said microelements thereon are uniquely aligned with each other.

2. The microelement assembly as claimed in Claim 1 wherein said means for kinematically interfacing said first and second substrates includes at least three kinematic protrusions disposed on said first surface of said first substrate and at least three kinematic receptacles disposed on said first surface of said second substrate.

3. The microelement assembly as claimed in Claim 2 wherein said kinematic protrusions are hemispheres.

4. The microelement assembly as claimed in Claim 3 wherein each said receptacle includes three hemispheres extending from said first surface of said second substrate.

5. The microelement assembly as claimed in Claim 4 wherein each said kinematic protrusion contacts all three hemispheres of one of said receptacles.

6. The microelement assembly as claimed in Claim 1 wherein each said substrate includes an electronic microassembly.

7. The microelement assembly as claimed in Claim 1 wherein each said substrate includes an optical microassembly.

8. The microelement assembly as claimed in Claim 1 wherein said first substrate includes an optical microassembly and said second substrate includes an electronic microelement.

9. The microelement assembly as claimed in Claim 1 wherein said first substrate includes a lenslet array.

10. The microelement assembly as claimed in Claim 9 wherein said second substrate includes an array of laser diodes.
11. The microelement assembly as claimed in Claim 10 wherein said first and second substrates are spaced apart by about 200 micrometers...
12. A method of fabricating a microelement assembly, said method comprising the step of:  
forming, at each of at least three mounting locations on each first surface of first and second substrates, corresponding protrusions and receptacles for kinematically interfacing said first and second substrates to each other such that said microelements thereon are uniquely aligned with each other.
13. The method as claimed in Claim 12 wherein said forming step includes the step of providing each first surface of said first and second substrates with a layer of photosensitive material; and thereafter forming a plurality of openings corresponding to the locations of said protrusions and receptacles.
14. The method as claimed in Claim 13 wherein said opening forming step includes a photolithography step.
15. The method as claimed in Claim 14 further comprising the steps of forming bumps in said openings; and thereafter heating said bumps to the melting point of the bump material and allowing said bump material to flow into hemispheres.
16. The method as claimed in Claim 15 wherein said bump forming step includes forming indium bumps.
17. The method as claimed in Claim 16 further including the step of removing the layer on photo-sensitive material subsequent to forming said bumps.

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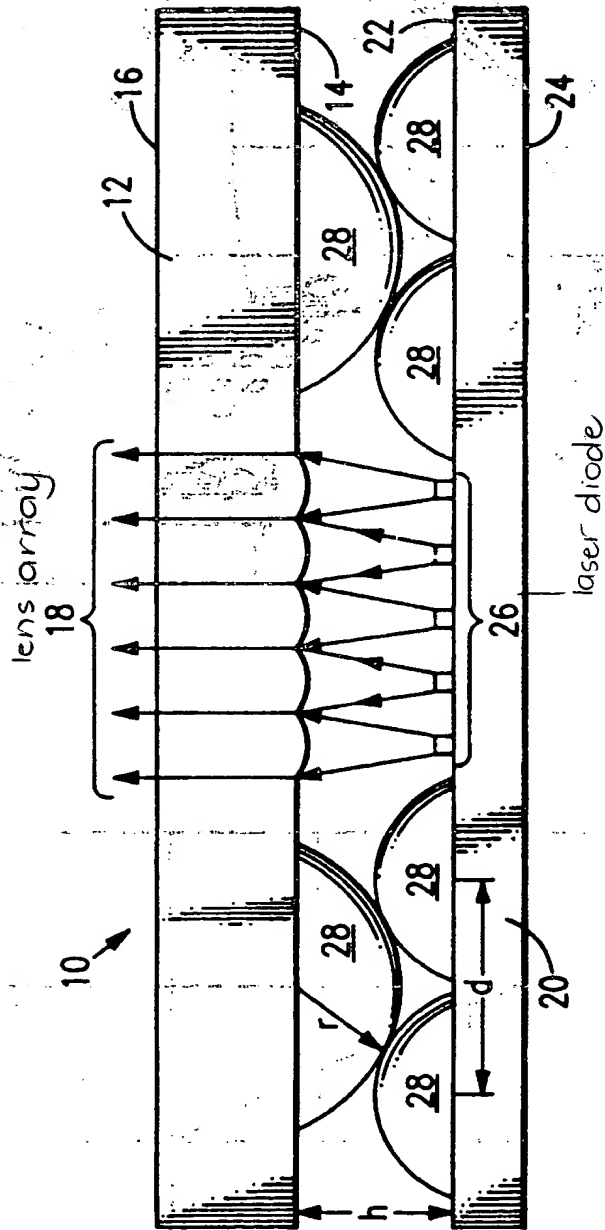
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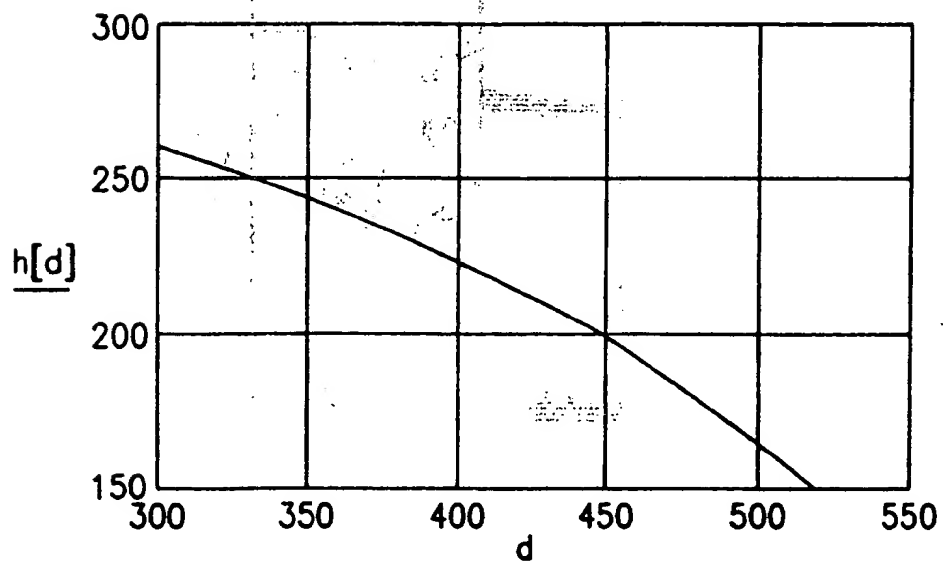
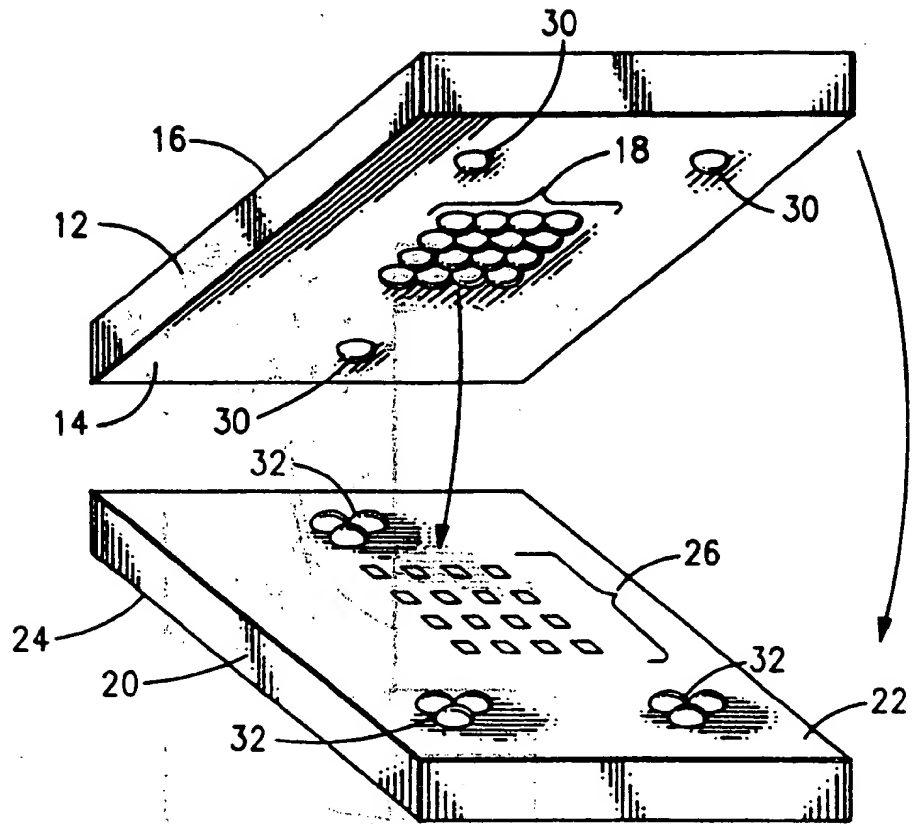
103  
claim 11



**FIG.1**



**FIG.2**



**FIG.3**

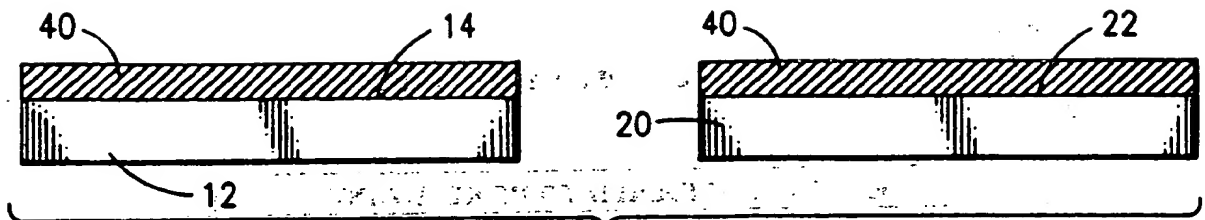


FIG. 4A

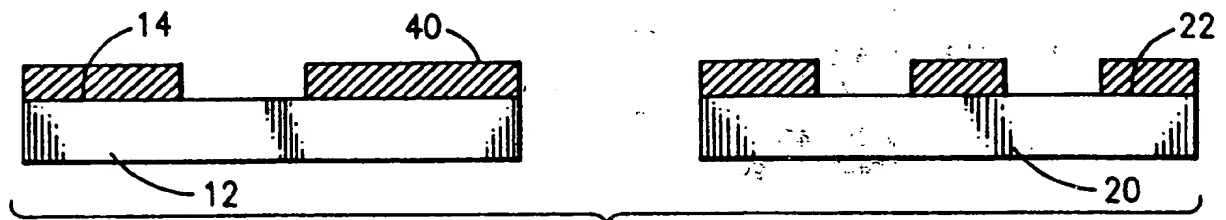


FIG. 4B

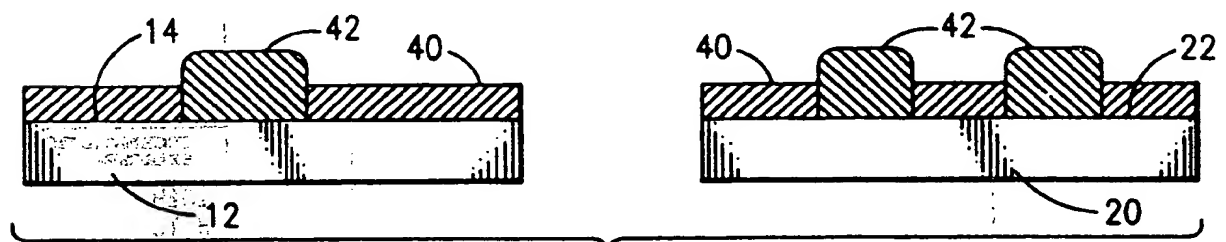


FIG. 4C

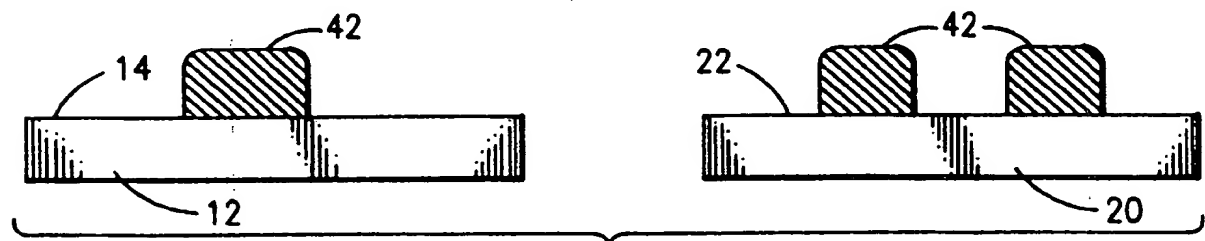


FIG. 4D

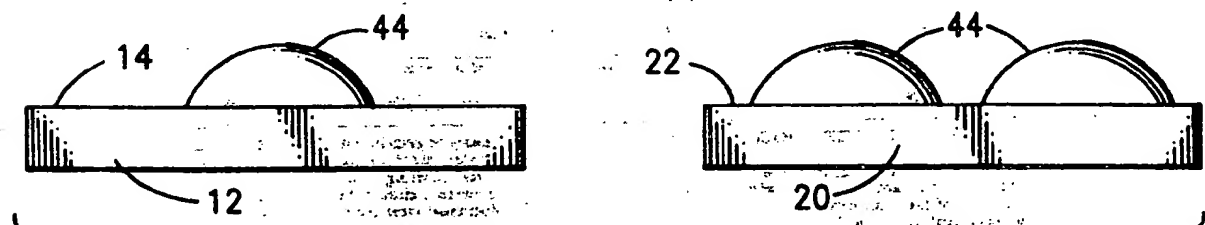


FIG. 4E



European Patent  
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# EUROPEAN SEARCH REPORT

Application Number  
EP 94 30 7487

## DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP-A-0 526 776 (IBM) * column 4, line 46 - column 6, line 2; figures 1-4 *	1,6-10	G02B6/42
A	EP-A-0 548 440 (IBM) * page 10, line 14-21; figure 4 *	1,2	
A	EP-A-0 355 478 (IBM) * abstract; figures 1,2 *	12-15	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			G02B H01L
The present search report has been drawn up for all claims			
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